Modeling For Both Deep Ocean And Coastal Wave-Wave Interactions: Implications For WAM

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LONG-TERM GOAL

My long term goal is to construct an accurate and efficient new WAM model, suitable for both deep ocean and coastal region.

OBJECTIVES

The central emphasis of the project is the construction of an efficient accurate source function for nonlinear wave-wave interactions (S_{nl}). We also will construct the proper numerical scheme, kinematics, and the various source terms (wind input function, and dissipation), based on rigorous physical principles and statistical data analysis. Ultimately, we will achieve a completely new WAM wave model for deep ocean and coastal regions, with potential capability to include the current-wave and atmosphere-wave interactions in a truly interactive mode.

Surface waves in coastal waters play a far more important role than in deep water. The motions of the waves can penetrate the whole water column to influence mixing, sediment

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transportation, turbidity, and circulation of the water mass. Most past efforts in wave modeling apply to deep water. However, there are crucial differences between deep water and shallow water wave dynamics. Our scientific objectives also include clarification of these differences and establishment of the proper representations of their dynamics in both deep ocean and finite-depth coastal waters.

APPROACH

We have investigated both deep ocean and coastal kinematics and dynamics, in preparation for construction of a new WAM model.

In order to obtain an accurate and efficient S_{nl}, we are developing a "Reduced Integration Approximation" (RIA), which is based on the highly nonlinear dependence the interaction coefficient, within S_{nl}, has on the wave number. From an analysis of the nonlinearity, we reduce the 3-dimensional integrations by Resio and Tracy (1982), hereafter denoted R-T, to a quasi-line integration. Resio and Tracy (1982) integrated the nonlinear Boltzmann integral for the wave-wave interactions along the resonant locus of interactions in wave-number space and reduced the Hasselmann and Hasselmann (1981)'s classical 5-dimensional integrations, hereafter denoted H-H, to 3-dimensional integrations. In reducing the dimensions of integration, this method significantly reduces the CPU time. Thus RIA provides substantial savings.

WORK COMPLETED

We had completed studies on the numerics and kinematics in FY97 (Lin and Huang, 1996a and b). In FY98, we completed the studies on the nonlinear four-wave interactions and five-wave nonlinear. We also have produced seven manuscripts, associated with the finished work (Lin and Perrie, 1997a, b, and c; 1998a, b, and c; Lin and Su, 1998).

We have developed a preliminary "RIA" source code for calculating nonlinear source functions. The documentation for RIA is in preparation. We have compared our model results with some published model results for a wide range spectra (wide, narrow, and split spreading angles). We are currently developing an independent pseudospectral method to calculate the nonlinear source function. Our object is to verify the accuracy of our nonlinear source function S_{nl} and to reduce the CPU time.

RESULTS

(1) Theory:

Resonant wave-wave interaction processes were studied, using the nonlinear dispersion relationship for finite depth water. The formulation was derived from a Hamiltonian representation. Our results show that four waves are needed for resonant interactions at all depths. Furthermore, when we consider the nonlinear dispersion relationship for

waves in intermediate water, two interaction modes can result, depending on the water depth and the nonlinearity. The first mode is the classic Phillips (1960) interaction, involving four waves of comparable wave lengths, which dominates in deep water. The second mode, which prevails in shallow water, still involves four waves, but with one component of vanishingly small wave number. Triadic shoaling interactions are an approximate asymptotic limit of the latter case.

Three-dimensional (five-waves) interactions may dominate when the spreading angle of the spectrum is very narrow and nonlinearity is greater than 0.3 (Lin and Su, 1998).

(2) Numerical Method:

The RIA method is based on Hamiltonian principles. To analyze the major solutions which we locate, we reduce 3 integrations of R-T to quasi-line integrations. Our method is both accurate and efficient, and also suitable for both deep ocean and shallow water(1997a and b). We compare our model results with published model results for a wide range spectra (both wide, narrow, and split spreading angles), and with 4 well-known methods, H-H, R-T, DIA (standard WAM model), and DIA2 (proposed 'new' WAM model). Our results showed:

a. We got very good agreement with H-H, R-T, Masuda (1980), and Masuda and Komatsu (1998) when the dispersion is linear. The most exciting thing about our results is that when the spectrum is split, all exact solutions (H-H, R-T, and RIA) generated similar horse shoe patterns. For a narrow spreading angle spectrum, our model results agree with those of Herterich and Hasselmann (1980). This is true in both deep ocean water and shallow water.

b. Our model results differ significantly from the results of DIA and DIA2.

c. Our model results agree well with the winter storm data from DUCK94 experiment (Lin and Perrie, 1998a).

IMPACT/APPLICATION

The means by which we have studied the coastal kinematics, dynamics, wave-wave interactions and our development of the RIA method is novel and appropriate for future investigations. Nonlinear wave-wave interactions need 4-wave interactions for all water depths. When the water depth becomes very small, one component must become of vanishingly small wave number. Previous work on triadic shoaling interactions represent an approximate asymptotic limit. We first developed this theory in 1997, which is supported by Zakharov (1998). The accuracy of this theory is a guiding light for future source code development.

RIA method is based on theory: the nonlinear interaction coefficient depends on the wave number in a highly nonlinear manner. Therefore, we are able to reduce the 3-dimensional integrations of R-T to a quasi-line integration. This is different from the (previous) approach using piece-wide approximations, which motivate DIA and DIA2 (Snyder et al., 1981). Recent tests comparing RIA to DIA and DIA2 at Vicksburg show (Jenssen et al, 1998) that the former is correct, but the latter is incorrect.

TRANSITIONS

The theory which we suggested above is accepted by the S_{nl} BE group. We hope that we can use it to significantly improve S_{nl} in WAM.

RELATED PROJECT

I have recently begun a collaboration with Dr. Scott Chubb who is in the remote sensing group in NRL (Washington DC) to study effects of seamounts to trap waves. I also have collaborated with Dr. Perrie at BIO (Dartmouth, Nova Scotia, Canada) to model and predict wave-current interactions in the St. Lawrence River and Gulf.

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